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SAMENESS-DIFFERENCE JUDGMENTS OF NUMEROUSNESS BY MONKEYS: *MACACA* *MULATTA* AND *MACACA ASSAMENSIS*

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ABSTRACT: Three of four monkeys were trained successfully on a series of number-related judgment problems ending with "same" and "different" judgments involving pairs of numerosness discriminanda. The discriminanda were black "dots" drawn on cards and constructed using controls to preclude the use of cumulative area or brightness cues and to make specific pattern memorization unlikely. On the final task, all possible same and different pairs of discriminanda representing the numbers 2 through 6 were used, and three monkeys met criterion (two successive sessions of 80% or more correct) in 80, 160, and 200 trials, respectively. Discussion considered possible underlying processes to explain the numerosness judgments as well as the implications of the present work for Piaget's views on conservation of quantity.

The numerical competence of animals has long been of interest (e.g., Honigman, 1942; Salman, 1943; Wesley, 1961; Davis & Memmott, 1982; Davis & Pérusse, 1988). However, concerning the early work, Wesley concluded that only Hicks' (1956) study of rhesus monkeys' (*Macaca mulatta*) ability to respond to "threeness" had been sufficiently free of confounding to show animals' use of number-related cues. Subsequently, several suitably controlled investigations have been reported; see Davis & Pérusse, 1988, for examples. In terms of well-controlled, fully-reported published studies, Thomas, Fowlkes, and Vickery's (1980) report that squirrel monkeys (*Saimiri sciureus*) can distinguish seven from eight entities ("dots") appears to have shown the possible upper limit of noncounting-based numerosness discrimination by animals. More recently, Terrell and Thomas (in press) also using squirrel monkeys, have shown a similar upper limit

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when the number-related discriminanda were the number of sides (or angles) of randomly constructed polygons. Most recently, Thomas, Phillips and Young (personal communication, August 13, 1990) have reported possibly similar upper limits for humans (*Homo sapiens*) using both dots and polygons as discriminanda.

The present study was suggested by the numerosness judgment capacity concept developed by Thomas and his colleagues (Czerny & Thomas, 1975; Thomas et al., 1980) and by previous investigations (Lin & Gong, 1989; Zhang, 1989). The use of numerosness discriminanda was extended to a new conceptual context, namely, whether monkeys can use such discriminanda to make "same" and "different" judgments. In addition to the implications of such judgments in terms of the concepts of same and different *per se*, such judgments have relevance to Piaget's views concerning the conservation of number.

METHODS

Animals

Three rhesus monkeys (*Macaca mulatta*) and one Assamese macaque (*Macaca assamensis*) were used as the subjects. The rhesus monkeys were: (a) Jia-jia, a laboratory-born female, 5 years old at the beginning of this experiment. She had received training involving numerosness discriminanda approximately two years prior to the present study and involving the use of numerosness concepts approximately one year before the present study; (b) Mei-ling a laboratory-born female, 1.67 years old when the experiment began which had no prior numerosness training; and (c) Dou-dou a wild-born female, 2 years old who was bought from the Beijing zoo for the present study. The Assamese macaque, Xiao-shan, was a laboratory-born male, 2 years old, with no prior research experience.

Apparatus and General Procedure

A modified Wisconsin General Test Apparatus, painted dark gray, was used. Within the testing apparatus, two stimulus-presentation boxes (12 x 14 x 15 cm) also painted gray were used. During testing the boxes were placed 3 cm apart. A colorless transparent glass of 12 x 14 cm was mounted in the front of each stimulus presentation box, and a stimulus card could be displayed behind the glass and in front of the box. Below each box, there was a food-well to hold the reinforcers.

When the experiment began, the animal was transported to a testing cage (35 x 40 x 50 cm) which was juxtaposed against the front

of the testing apparatus. A screen that could be raised and lowered was placed between the testing apparatus and the testing cage. At the beginning of each trial, the screen was lowered to prevent the monkey from seeing the experimenter place the discriminanda in their glass holders and the reinforcer beneath the appropriate stimulus presentation box. The screen was then raised to display the discriminanda, and the whole apparatus was pushed towards the animal and within its reach to allow it to make a response. Following the response, the screen was lowered to enable the experimenter to set the discriminanda and reinforcer for the next trial. In order to make a response and gain the reinforcer, the monkey could push aside the stimulus presentation box associated with the correct discriminandum for that trial. Incorrect responses were not reinforced, and the stimulus presentation boxes were withdrawn to prevent the monkey from correcting its response.

Discriminanda

The discriminanda were black-filled circles (hereafter, these will be referred to as "dots") that were drawn on white cards. The cards were 11.5 x 13 cm and from 2 to 6 black circles were drawn on each card. In order to control against the use of the dots' cumulative areas as discriminative cues or the differential brightness cues resulting from the cumulative area of the black dots, the areas of the circles were varied. Three diameters of black circles were used, 2.5 cm, 1.9 cm and 1.4 cm, and these were selected quasi-randomly for the construction of each card. In order to avoid a fixed pattern or repeated patterns in the construction of the discriminanda, a 16-point (4 x 4) grid was used to determine the loci of the black circles on the cards; the placement of the dots on the grid was determined quasi-randomly. Each number from 2-6 was represented by 25 individually constructed cards and each card might be displayed in the upright or inverted position; therefore, each number was represented by 50 discriminable patterns. The left-right position of a given card in conjunction with the two stimulus-presentation boxes was determined randomly.

Training Procedures

Initially, the monkeys were exposed to the experimenter and apparatus in order to let the animals become habituated to the handling required, the experimenter, and the general demands of the experimental situation. The following six tasks were used in the order listed. Each animal was trained on each task until it met a criterion of 80% or greater accuracy for two successive days or until it was judged that the animal was unlikely to attain criterion.

1. *Discrimination training: 3 vs. 5.* The purpose of using the first task was to get the animal to discriminate between exemplars of the numbers 3 and 5. Responses to the discriminanda with 5 dots were reinforced.

2. *Discrimination training to respond to "more" using pairs constructed of cards with 2, 4 or 6 dots.* Responses to the card with more dots in each pair of numbers were reinforced.

3. *Discrimination training to respond to "more" using pairs constructed of cards with 2, 3, 4, 5, or 6 dots.* This task was similar to the preceding task except that cards with 3 and 5 dots were also used.

4. *Sameness-difference pretraining.* This pretraining task introduced the possibility of having the subject learn to respond by using "same" and "different" numerosness judgments. To represent "different," one card with 3 and another card with 5 dots were used and to represent "same," a pair of cards, each with 3 dots was used. When the stimulus pair 5-3 was displayed, the number 5 was always displayed on the left and the reinforcer was available when the monkey responded to the "5" card on the left. When a same-pair (3-3) was presented, reinforcement was available when responses were made to the "3" card on the right. In quasi-random order, 20 "same" and 20 "different" trials were presented each day. It was realized that solutions other than responding to "same" or "different" were possible. For example, the monkeys merely had to learn to respond to "5" when it was available and to the "3-on-the right" when "5" was not available. However, as a form of pretraining for same and different numerosness judgments, it was believed that this was a useful procedure with which to begin.

5. *Sameness-difference training using cards with 2, 4, or 6 dots.* The difference-pair discriminanda consisted of 6-4, 6-2, and 4-2 dots, and the same-pair discriminanda consisted of 6-6, 4-4, and 2-2 dots. These six stimulus pairs were presented in quasi-random order so that each stimulus pair appeared approximately equally often during each day's 40-trials session; that is, each pair was presented 6 or 7 times daily. Correct responses to a "different-pair" were denoted by responding to the card on the left and correct responses to a "same-pair" were denoted by responding to a card on the right.

6. *Sameness-difference training using cards with 2, 3, 4, 5, and 6 dots.* The difference-pairs were 2-3, 3-4, 4-5, 5-6, 2-4, 3-5, 4-6, 2-5, 3-6, and 2-6 and the same-pairs were 2-2, 3-3, 4-4, 5-5, and 6-6. Twenty same and 20 different pairs were presented in quasi-random order during each session. However, selection among the 10 different-pairs was also in quasi-random order to insure that it was likely that the easier (e.g., three or four numbers apart) and harder (e.g., one or two numbers apart) difference-pairs occurred equally often during a session.

TABLE 1
Trials to Criterion (TC) and Mean Percentage Correct (%)
During the Criterion Sessions for the Three Successful
Monkeys on the Six Tasks

Measures	Subjects					
	Mei-ling		Jia-jia		Xiao-shan	
	TC	%	TC	%	TC	%
Tasks						
1	920	85	580	88	506	88
2	80	80	100	83	60	90
3	120	81	60	82	60	85
4	230	83	320	86	180	85
5	120	84	210	87	60	82
6	200	84	160	88	80	81

RESULTS AND DISCUSSION

Three of the four monkeys reached the 80% criterion on all tasks. For the three successful monkeys, trials to criterion and average percentages correct in the two sessions used to define criterion may be seen in Table 1. One of the rhesus monkeys (Dou-dou) failed to reach criterion in 1,155 trials on the first task, and her training was terminated.

As shown in Table 1, the monkeys acquisition of Task 1 required the most trials of any of the six tasks. There was evidence of strong transfer of training from Task 1 to its related Tasks, 2 and 3. Same-different training was introduced in Task 4, and its acquisition was accomplished in fewer than half the trials taken by the best monkey on Task 1. These data suggest strong general transfer of training among the numerosness tasks regardless of whether numerosness discrimination or same-different numerosness judgments were required. In view of the number of unique discriminanda used together with the relatively few trials to criterion on Tasks 2-5, it appears that the monkeys were responding to numerosness on a conceptual basis.

GENERAL DISCUSSION

Six tasks were used in the present research. The first three involved numerosness discrimination judgments and the last three involved numerosness judgments based on "same" and "different." That three of the four monkeys were highly successful on all six tasks

indicates that numerosness judgments are well within the capacity of the genus, *Macaca*.

Davis and Pérusse (1988) suggested several possible processes that nonhuman animals might use to make numerosness judgments. However, Terrell and Thomas (in press) and Thomas and Lorden (in press) have argued that only two processes can account for all reports of animals' use of number, namely, counting or prototype matching. They noted that counting is controversial and that the evidence for counting depends on the definitions and criteria that one uses. They suggested that many investigators appear to agree that evidence for Gelman and Gallistel's (1978) first three principles is necessary (viz., *one-to-one correspondence* between counting "tags" or symbols and items to be counted; the application of the tags in *stable-order*; the *cardinal principle* according to which the last tag applied defines the number of items in the counted set) and they questioned whether such evidence had been shown sufficiently in any animal study. They also suggested that the prototype matching interpretation could explain any animal research on numerical competence to date. According to the prototype matching interpretation, a subject acquires through experience an average representation (or prototype) of sets of items representing particular number categories; these average representations may be precise (e.g., "threeness," "sevenness," etc.) or imprecise (e.g., "manyness") and may be used in numerosness judgments on an absolute (e.g., "threeness") or relative (e.g., "more" or "fewer") basis. Applied to the present work, the acquisition of numerosness concepts on a prototype matching basis underlies both the discriminative and same-different numerosness judgments. Same-different judgments also superimpose a second kind of category judgment on the required numerosness judgments.

While Piaget is usually remembered as being a developmental psychologist, it is clear from his writings that he viewed himself as being a constructive epistemologist. Piaget's research tended to address the ontogenetic development of cognitive structures and skills in children, but he made it clear (e.g., Piaget, 1971) that he viewed his work in phylogenetic contexts as well.

Recent reviews of the animal-Piagetian research have reached widely different conclusions. Thomas and Walden (1985) expressed a conservative view and suggested that the two most studied concepts in animals, object permanence and conservation, pose fundamental problems that may not be addressable using animals (e.g., they argued that linguistic explanations may be essential in the evidence for conservation). However, Doré and Dumas (1987) were much less critical of the animal-Piagetian research. Doré and Dumas cited Thomas and Walden, but it appeared that they had not considered fully the objections raised by Thomas and Walden.

In any event, the successful same-different numerosness judgments shown in the present study appear to be related directly to an argument presented by Piaget (1968) concerning the evidence for the conservation of number, and we deem it to be useful to present our findings in this context. Commenting on a study by Mehler and Bever (1967), Piaget (1968) argued:

. . . conservation of equality . . . can be shown only if two rows of equal numbers are presented and one row is then spread out or crowded; or at least if two rows of unequal length are presented without modification (p. 978).

Our evidence for “same” judgments of numerosness (the “different” judgments in this case served as controls to insure that the subject was judging same and different differentially) appears to be more rigorous than the evidence described by Piaget in his comment on Mehler and Bever as being the “least” required to show conservation of equality. In Mehler and Bever’s case, the entities were the same size permitting confounded judgments of *equivalence* based on cumulative area or volume cues. Equivalence in our case can be based only on numerosness, as the sizes of the entities were varied.

In terms of conservation, the issue that remains to be resolved is whether the judgments in our study reflect the monkeys’ abilities to perceive the perceptual equivalence of numerosness discriminanda as opposed to the conservation of number. A liberal interpretation is that we have provided evidence for conservation that is more rigorous than the minimal evidence that Piaget himself said was required. A conservative interpretation is that resolution of the distinction between perception judgments of equivalence and the true conservation of number requires the subject’s verbal explanation, as Thomas and Walden (1985) have argued. The resolution of this issue is beyond the scope and means of this article to provide. In any case, it is reasonable to say that the present research provides good evidence for essential prerequisites to the conservation of number if not for the conservation of number itself.

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AVOIDANCE OF NEW OBJECTS BY THE BLACK RAT, *RATTUS RATTUS*, AFTER OBJECT PRESENTATION AND CHANGE

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ABSTRACT: This work compares object replacement and object presentation as causes of avoidance (new object reaction or neophobia). The movements of wild black rats, *Rattus rattus*, living in an automated plus maze were recorded (1) after replacing a familiar object (in a familiar place) with a series of novel objects, (2) after presenting a novel object in a familiar place where there had been no object. Replacing one object by another did not delay entry to the maze arm containing it. In contrast, the presence of a new object in a previously empty arm did increase the latency of the first approach (new object reaction), although after the first entry, the rate of visiting the arms and the time spent in them, which are measures of subsequent approach, were unaffected. Hence, this form of neophobic behavior was evoked only by the presence of a new object where none had been before. Differences with earlier reports can be resolved in most cases when attention is paid to the difference between presentation and replacement.

When an object such as an iron strip or a block of wood is placed in the foraging area of wild rats (*Rattus*) of a commensal species, the rats usually avoid it. (On *Rattus norvegicus*, see Barnett, 1958; Calhoun, 1962; Chitty & Shorten, 1946; Shorten, 1954; on *Rattus rattus*, Cowen, 1976; Cowan & Barnett, 1975.) Chitty and his coworkers called this behavior "new object reaction" (Chitty & Kempson, 1949; Shorten, 1954). Later it was named "neophobia" (Barnett, 1958), with the same reference to maintaining a distance from a location of change.

This behavior should be distinguished from "flavor neophobia," that is, eating or drinking less than expected when a novel mixture is offered (Carroll, Dinc, Levy & Smith, 1975; Domjan & Gillan, 1976; Miller & Holzman, 1981). In studies of flavor neophobia, subjects are usually described as consuming appreciable amounts of food; hence the "neophobia" does not prevent the animals from making and maintaining contact with the source of novelty. The assumption that this behavior is equivalent to avoidance of new objects by commensal rats

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may have arisen from the use, in some experiments, of reduced food intake as a measure of locomotor avoidance when a new object is placed near the food supply (Barnett, 1958; Shorten, 1954; for further discussion see Barnett, 1988). The focus in the present paper is on locomotor avoidance of objects. For clarity in the account that follows, the original name, new object reaction, is used.

New object reaction occurs only in a familiar region. For example, in experiments by Cowan (1976), avoidance by *R. rattus* was observed only when a new object was placed in an environment previously visited by the rats; the presence of the same object in a newly accessible region did not interfere with exploration (see also Calhoun, 1962, on *R. norvegicus*). Transferring an object from one place to another, in a familiar environment, can also lead to avoidance by rats of both species (Cowan, 1976; Shorten, 1954). In contrast, removal of an object from a familiar environment has no effect on *R. norvegicus* (Shorten, 1954).

In the experiments just described, the method was always object presentation (or removal). An alternative is object replacement, that is, substituting a new object for a familiar one in the same place. This too has been said to cause avoidance by both *R. norvegicus* and *R. rattus* (Advani & Idris, 1982; Cowan, 1976; Galef, 1970; Mitchell, 1976; Shorten, 1954). But Galef (1970) and Mitchell (1976) used food consumption as their behavioral index, and both reported relatively short delays before feeding; and, of the three tests mentioned by Shorten (1954) which seem to have involved replacement (see pp. 311, 318, 319), only one led to noticeable avoidance. In related work, olfactory changes caused by applying unfamiliar substances to an object, such as a food container, or by washing it, had no effect (Cowan, 1976; Shorten, 1954). Together, these experiments suggest that avoidance is more reliably evoked by adding new entities than by altering existing ones.

The present work gives further evidence on the different effects of object presentation and object replacement on new object reaction. As in earlier studies from this laboratory, locomotion into an area was recorded directly. In addition, novel objects were in places separated from those where food and water were found, so that new object reaction could be observed independently of eating and drinking.

METHOD

Animals

Eight male and eight female *Rattus rattus* were used for Experiment 1 on object replacement. Eight males were used for Experiment

2 on object presentation; one group was sufficient in this case, to determine whether any aspect of the experimental situation precluded the usual new object reaction. The animals were trapped in the roof of a building at the Australian National University. Their age at trapping was estimated at 30-50 days. Isolation is tolerated well by this species. Before the experiment, therefore, until they were about one year old, they were housed individually in wire cages (36 x 30 x 25 cm), with water and food (Mecon Rat and Mouse Cubes from Fidelity Feeds, Murrumburrah, N.S.W) always available. During the experiments, all animals fed well: daily group means for food removed from the hopper were 19 to 26 g.

Apparatus

While under experiment, each rat lived alone in one of four plus mazes (Figure 1; *cf.* Barnett & Cowan, 1976). Two adjacent arms contained, respectively, a basket of food and a water bottle, each at the end of the arm. The floor of the food arm was covered with sawdust. The other two arms contained the objects used in the experiments. Each maze was lit from above by a 40 W circular fluorescent tube. The central compartment and food arm had black plastic tops; the other arms were covered with clear Perspex. The mazes were in a sound-insulated room kept at 19-22°C, on a 12:12 light-dark cycle with darkfall at 1900 hours.

As in earlier research (Cowan & Barnett, 1975), a "visit" to an arm began when the photocell beam at the end of the arm was broken, and ended when the beam at the beginning of the tunnel leading to the arm was broken (Figure 1). These events were logged on a Digital PDP 8/e computer, with a precision of 0.01 min.

Each object used to test for new object reaction was fastened by a screw to a metal platform 1 cm high; the platform covered the floor of the arm beyond the tunnel (Figure 1). The screwhole in a platform was centered transversely in the arm and was 9.5 cm from the end of the tunnel, immediately in front of the distal photocell beam.

Fourteen kinds of object were used; each was 2 to 4 cm high and 1 to 4 cm wide (Figure 2). All objects were of metal or glass and so could not be gnawed apart. In the figure, objects not radially symmetrical are shown as they would appear from the tunnel of an arm.

Procedure

After a 24 h period ending at 1200 hrs, during which all arms were open and the first pair of objects were in place, rats were given daily trials lasting from 1800 (1 h before darkfall) until 2300 hrs. During each trial the food and water arms were closed, to avoid com-

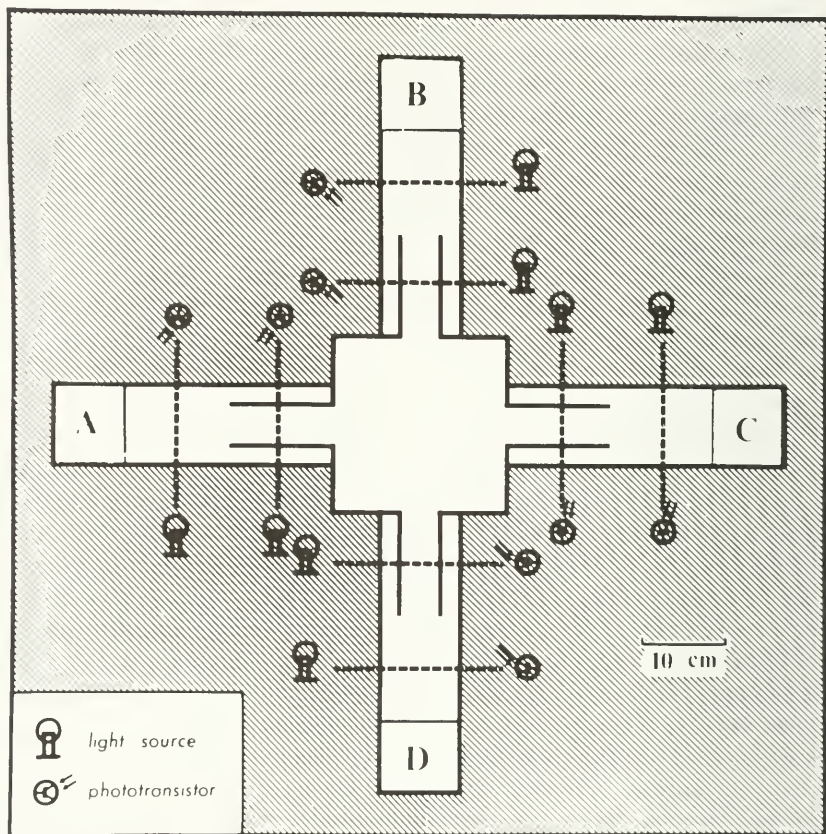


FIGURE 1. Schematic diagram of plus maze showing locations of photocell beams in each arm. A tunnel occupied the first 10 cm of each arm and was 7.5 cm wide, while the width of the open arm was 10.5 cm. Food and water were in the end compartments of arms A and B, respectively. Arms C and D were open during the trials.

peting responses that might affect locomotor activity in the experimental arms. After a trial, the experimental arms were closed and the food and water arms reopened. Objects in the arms were replaced on the day after each trial at about 1300 hrs. The used objects were cleaned for further use by washing with soap and water, thorough rinsing and immersion in 70% alcohol. Food was replenished at this time and water bottles were refilled.

In Experiment 1, on object replacement, the females were exposed to an object in each object arm for 8 preliminary trials. Owing to an oversight the males were similarly exposed for only 7 days. Either period is more than enough for measures of locomotor exploration to stabilize (Cowan & Barnett, 1975). During this condition, each

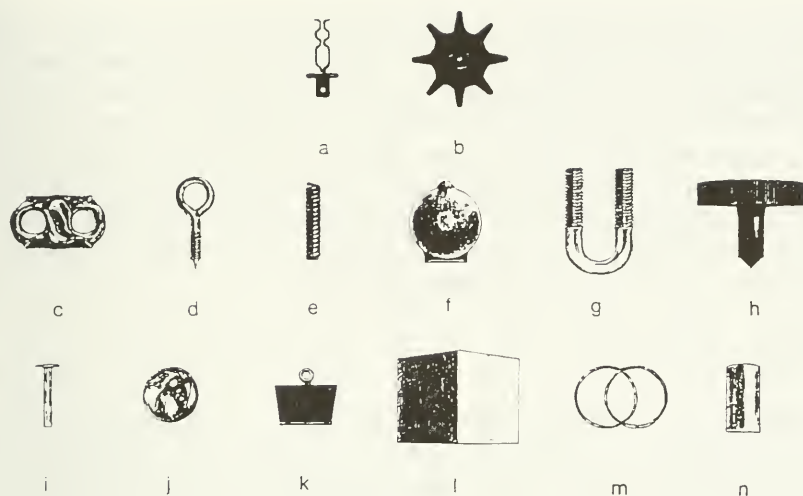


FIGURE 2. Objects placed in arms: a. Grille clip, b. Gear, c. Cable clamp grip, d. Screw eye, e. Spring, f. Disc, g. Cable clamp thread, h. Camera screw, i. Paper binder, j. Marble, k. Paper clip, l. Cube, m. Rings, n. Testtube cap. Objects in order presented to one rat in Exp. 1: a and b in preliminary condition, b replaced by c, d,..., n in experimental condition. For corresponding rat in Exp. 2, a and c appeared on Trial 8, c was replaced as above.

object was replaced daily by another of identical type, for example, a grille clip by another grille clip. Twelve experimental trials followed: in each, a new type of object was placed in one arm (changing or C-arm), while the object in the other arm (unchanging or U-arm) was replaced, as before, by another of the same type.

In Experiment 2, on object presentation, the preliminary condition lasted for 7 days, during which both object arms were empty. On Day 8, objects were put in both arms. On the next 11 trials a new type of object was put each day in the C-arm, while the object in the U-arm was replaced by another of the same type. Hence the procedure during the experimental trials was identical to that of Experiment 1.

For the preliminary condition in Experiment 1, four pairs of objects were chosen at random: grille clip and gear (Figure 2a,b), cable clamp grip and screw eye (c, d), spring and disc (e, f), cable clamp thread and camera screw (g, h). Each pair was used with the two rats run in the same maze, so that a given object appeared in the left arm for one rat and in the right arm for the other. In addition, the 12 kinds of object that were substituted in the C-arm were divided into groups of six (groups "A" and "B", respectively, shown in Figure 2; group A consisted of objects c through h and group B of objects i through n). All objects in one group were presented before objects in

the other; half the subjects were exposed first to group A objects, and half to group B. For each group of objects a single random order of presentation was derived: each rat was exposed to the objects in this order beginning at one of four points. For example, for one rat the order of the objects replacing object b was c, d, e, f, g, h, i, j, k, l, m, n; in another case, d was replaced by e, f, g, h, a, b, k, l, m, n, i, j. In this way the transitions between objects on successive trials were similar for all rats, although the new object presented on trial n was different for each subject in an experimental group.

Statistical Analysis

The measures of behavior in the maze were i) the latency, that is, the interval between the opening of an object arm and the first breaking of the distal beam, ii) the hourly visit rate to each arm, based on total visits and the duration of the trial after the first visit to that arm, iii) the mean visit duration, iv) the mean inter-visit interval (IVI). These measures were chosen instead of the number of visits and total visit duration used earlier (reviewed by Barnett & Cowan, 1976) because they meet the conditions of logical independence and generality more adequately.

Differences between groups and effects of experimental conditions were analyzed with repeated measures ANOVAs and Newman-Keuls tests. For this analysis, trials were grouped in blocks of four (or three for the second block of preliminary trials for males), and log-transformed values were used. In Experiment 2, missing data due to new object reaction precluded the use of ANOVAs except for latencies. Paired comparison t tests based on all rats in each experiment were used to evaluate differences between the last preliminary and first experimental trials. Trends across trials during each condition were analyzed with tests for linear regression and deviations from it. (The latter were never statistically significant and are not considered further.) Stability of differences between subjects in each experimental group was evaluated with Kendall's coefficient of concordance, W , for each measure across trial blocks.

RESULTS

During the preliminary trials of both experiments, the major trends were declines in latencies and visit rates for both arms (Table 1). For the most part, these took place over the first three trials, and tests in which Trials 1 and 2 were omitted showed no significant trends over the remaining days ($p > .10$). The latencies of the fe-

TABLE 1
Activity Means for First and Last Trials in Each Condition

<i>Expt Sex</i>	<i>Trial and Arm</i>							
	<i>First</i>		<i>Last</i>		<i>First</i>		<i>Last</i>	
	<i>Preliminary</i>		<i>Preliminary</i>		<i>Experiment</i>		<i>Experiment</i>	
	<i>U</i>	<i>C</i>	<i>U</i>	<i>C</i>	<i>U</i>	<i>C</i>	<i>U</i>	<i>C</i>
Latencies (min)								
1 f.	115.9	107.0	71.8	67.8	82.7	80.5	63.1	60.1
m.	39.7	47.4	18.7*	22.4	18.0	19.4	22.2	16.8
2 m.	35.5	71.5	11.6+	13.9*	159.3	104.5	104.0	122.2
Visit Rates (no./h)								
1 f.	11.9	8.6	6.1	3.4*	6.5	4.9	2.1+	2.6+
m.	9.6	15.0	3.1 [!]	3.6 [!]	3.4	4.0	2.6	3.0
2 m.	13.7	10.9	3.1 [!]	3.2 [!]	2.2	2.3	1.4	2.6
Visit Durations (min)								
1 f.	1.6	1.3	2.7	4.6	4.2	1.3	1.5	13.4
m.	1.1	1.4	9.0*	2.0	6.0	4.4	11.9	1.2
2 m.	2.6	1.9	3.3	5.2+	3.2	3.2	12.1	3.0
Inter-Visit Intervals (min)								
1 f.	3.1	3.5	5.8	5.2	5.3	6.0	18.8*	8.4
m.	2.2	3.9	3.5	6.0	4.5	4.6	5.2	6.0
2 m.	1.8	2.1	3.8	9.8*	8.9	17.1	11.8	4.9

U = U-arm, C = C-arm. Superscripts under last trial of each condition are results of trend tests for each arm in that condition. [!] $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

males, however, varied markedly, and the trends for this group over the whole condition were not statistically significant (Table 1). Latencies for females were also greater than for males: for the U-arm, $F(1, 14) = 7.53$, $p < .025$; C-arm: $F(1, 14) = 5.48$, $p < .05$. Visit durations and IVIs of all groups also lengthened during this condition (Table 1). During the experimental trials there was evidence of a further decline in activity.

In Experiment 1, replacing objects in the C-arm had no evident effect on behavior (Table 1). In particular, for the comparison of latencies on the last preliminary and first experimental trials, $t(15) = .58$, $p > .25$ (one-tail). As a further test of avoidance, the proportion of trials on which the first choice was the C-arm was computed for each animal. For the females, the means for preliminary and experimental trials were 0.44 and 0.41, respectively, and the mean for the last six experimental trials was 0.44. For the males, the corresponding fig-

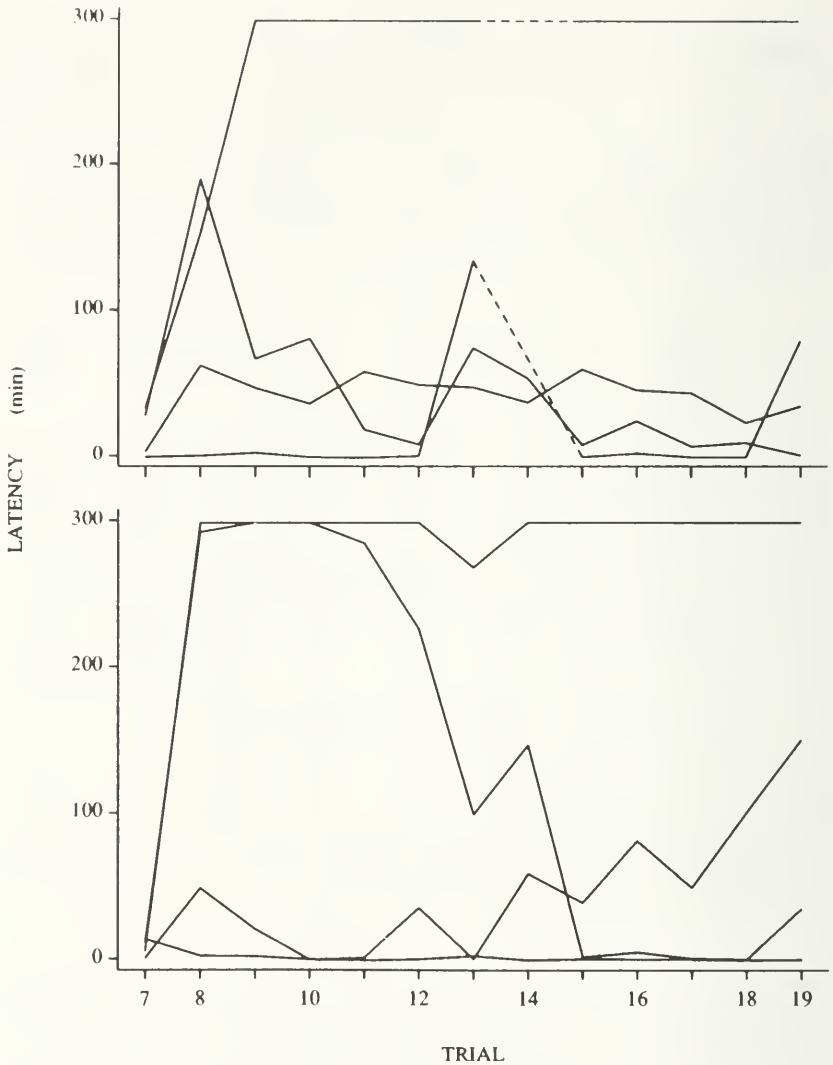


FIGURE 3. Latencies to enter arms, for individual rats in Experiment 2 (means of U- and C-arms on each trial). For clarity, data are shown in two panels. Dashed lines indicate lost data for two rats on Trial 14. U-arm (top); C-arm (bottom).

ures were 0.38, 0.39, and 0.38. This measure, therefore, also gave no evidence of avoidance of the C-arm during the experimental trials.

In Experiment 2, as expected, the first appearance of objects in the arms increased the latency of most rats (Table 1, Figure 3). Both comparisons between the last preliminary and first experimental trials were statistically significant (U-arm: $t(7) = 3.05, p < .01$; C-arm:

$t(7) = 2.03, p < .05$ (one-tail)), and corresponding results were given by the ANOVAs. In addition, a combined analysis of latencies for the male groups of both experiments yielded statistically significant effects for Groups \times Trial-Blocks (U-arm: $F(4, 56) = 3.57, p < .025$; C-arm: $F(4, 56) = 3.30, p < .025$), but not for either factor alone. Other behavioral measures were unaffected ($p > .10$).

The absence of differences in the behavioral measures, apart from latency, does not preclude temporary effects. In particular, visits might be shorter and more frequent while the animal is habituating to the new object. Examination of times and durations of initial visits on the last preliminary and early experimental trials showed no obvious changes. When mean durations of the first five (10) visits on the last preliminary trial were compared with those of the first five (10) visits after object presentation, no statistically significant effects emerged, ($p > .05$). The absence of behavioral effects after the first arm entry is the more notable in view of the stability of individual differences in all measures in both experiments, as shown by Kendall's W (in most instances, $p < .025$).

DISCUSSION

The measures of latency and visit rate during the preliminary trials yield evidence on new place reaction at variance with other accounts. Latency, a measure of avoidance, declined steeply during this condition. But visit rate, a measure of approach, also declined, especially between Trials 1 and 2. The latter finding accords with the results of earlier work on several species (Chopra & Sood, 1984; Cowan, 1976, 1977; Cowan & Barnett, 1975) in which the neophilic effect of new locations has been emphasized. The changes in latency, however, suggest a brief initial avoidance of such places. This effect may have been due, in part, to habituation to the disturbance at the beginning of each trial, but it is consistent with findings on domestic Norway rats (reviewed by Wallace, 1988).

In Experiment 2, as expected, the first appearance of an object resulted in avoidance of the arm containing it. This was shown by the latency of the first visit to the arm within the daily trial, an effect that sometimes persisted unabated for the entire 12 day period. The wide range of scores on this measure corresponds to earlier findings (Barnett, 1958; Cowan, 1976).

The importance of recording latency is illustrated by the fact that, in the present experiments, it was the only measure to show an effect of presenting a new object. Rats that entered the arms, whatever their latency, visited each arm at about the same rate as before and remained in the arms for similar durations. Individual differ-

ences were also stable. These results clarify previous findings with the plus maze, that showed effects of new objects on entrance latency, number of visits and time spent in the experimental arm (Cowan, 1976, 1977; Cowan & Barnett, 1975); it now appears that the latter effects are secondary to the longer latencies. At the same time, the present results are consistent with those of earlier experiments on domestic *R. norvegicus* (Barnett, Smart & Widdowson, 1971) and *R. rattus* (Cowan & Barnett, 1975), in which duration of activity outside the nest was maintained in the face of environmental alterations.

In contrast to the sudden appearance of an object, drastic changes in the shape and minor changes in the size of an object had no discernible effect on any measure of movement. Yet observations on the sensory abilities of *R. norvegicus* suggest that our rats (though of a different species) would have detected the change of objects both visually and tactually. (1) Experiments on visual discrimination have shown the distinctiveness and equivalence of different patterns to be remarkably similar for rats and human beings (Lashley, 1938). Findings on visual acuity also indicate that differences such as those between the objects (Figure 2) are well within their powers of discrimination (Birch & Jacobs, 1979). (2) Since each object partly blocked the arm, the rat had to touch it to break the distal photocell beam and record a visit; hence, there was also tactile input. In similar conditions, domestic rats respond to object replacement within seconds of encounter, by grasping and manipulating the object (Wallace, 1978) or by prolonged investigation (Berlyne, 1950; Blanchard, Shelton & Blanchard, 1970). Also relevant are observations by Shorten (1954) and by Southern, Watson & Chitty (1946) of new object reaction after presentation, which evidently depended on tactile cues.

The behavior of our rats after object replacement and object presentation shows that they perceived the two situations differently. Two explanations are tenable. (1) Rats may respond to the amount of novelty, that is, both to the magnitude of change in a single property and to the number of altered features. If so, avoidance would occur when a threshold value is exceeded, and this must have happened in Experiment 2 but not in Experiment 1 (*cf.* Berlyne (1960) on the behavioral effects of "collative variables"). (2) Alternatively, they may display avoidance only after a change in the object-in-location relationship, and not to changes in the attributes of an object. If object replacement in Experiment 1 was perceived as alteration of an object already in that location, there would then be no avoidance. This hypothesis is implied in the definition which restricts the term neophobia to "the avoidance of unfamiliar objects in a familiar environment" (Barnett, 1981).

Some laboratory studies, in which avoidance by *R. norvegicus* has been attributed to object replacement, seem in conflict with the results of Experiment 1, but these experiments combine both presenta-

tion and replacement (Braveman, 1978; Galef, 1970; Mitchell, 1976). The rats had access to food or water for a short period daily, and object replacement consisted of changing the food or water container; but this was put in a place where, for almost 24 h, there had been no object at all. Shorten (1954) observed avoidance when an object was removed and replaced after only 1 h. Braveman (1978) and Galef (1970) also put the new container in a different place for the test trial: their method is therefore properly described as object presentation after object removal. In addition, in each of these studies, approach was measured indirectly, by food consumed or latency to feed; hence, effects on feeding were not distinguished from changes in locomotor approach. No conclusions can be drawn regarding Shorten's (1954) field observation of avoidance after replacement, since the description of methods is incomplete.

Studies on *R. rattus*, by Cowan (1976, 1983) and Advani & Idris (1982), seem to give valid evidence of avoidance due to object replacement. But, in both, the index of avoidance is a decline in food consumption. (In related experiments by Mitchell, Kirschbaum & Perry, 1975 and by Mitchell, 1976, when *R. norvegicus* were presented with a novel container and a familiar one, at first they fed almost exclusively from the latter). Perhaps object change can suppress feeding without affecting movement toward the changed object. We need to know much more about the relationship between feeding behavior and new object reaction.

With reference to the behavior of wild rats of commensal species, Barnett (1981) wrote: "The question of what is, for a rat, a 'new object' has yet to be fully answered." The studies cited above and in the introduction, together with our present findings, take the analysis of new object reaction and related phenomena some way further: (1) The response of wild rats to a *new place* is mainly neophilic, but may include a brief neophobic component. (2) "Flavor neophobia" should be distinguished from the response to new objects; how it is related to new object reaction is still unclear. (3) Substituting one object for another, in a familiar place, has little or no effect on movements. (4) Putting a strange object in a familiar place, where none had been before, is likely to induce prolonged avoidance of that place, but only by rats of commensal species (*cf.* Bammer, Barnett & Marples, 1988). The last finding conforms with the suggestion that new object reaction is due to natural selection in environments where rats are subject to vigorous human predation.

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THE STUDY OF ANIMAL BEHAVIOUR IN INDIA: ORIGIN AND CURRENT STATUS

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ABSTRACT: Recorded observations on animal behaviour in India date back to ancient times. Behaviour of various animals was observed and described in ancient Indian classics. Many species of animals have been described as 'Vahanas,' that is, animals ridden by various Hindu deities. The sculptures and drawings of a number of deities also include these mounts with their characteristic behavioural patterns. However, scientific investigations on animal behaviour is a recently developed branch of biological science in India, initiated in the late 1950's. Systematic ethological research on various species of Indian animals was begun only in early 1970's, after the formation of the Ethological Society of India. At present a variety of topics such as foraging and feeding behaviour, habitat selection, social and reproductive behaviour, chronobiology, chemical communication signals and neurobehaviour are being investigated by Indian ethologists, who are mainly zoologists, and a few psychologists. A wide range of species from lower metazoa to higher vertebrates are observed by ethologists in India. An analysis of the development of ethology in India indicates that the progress of this discipline as a major field of research and teaching in India is satisfactory. Further, if the present trend is maintained, ethology should develop as a major discipline of animal research in India by the year 2000.

INTRODUCTION

India has a rich cultural and religious heritage. Long before the dawn of history, humans appear to have had practical knowledge in biology. Human beings have long been systematising their knowledge of the plants and animals amongst which and on some of which they lived. However, the information is scattered and incomplete. Much of the cultural and religious heritage of India is oriented around a number of plant and animal forms (Rao, 1957).

ANIMAL BEHAVIOUR IN ANCIENT INDIAN CULTURE

Recorded observations on animal behaviour in India date back to ancient times, and the behaviour of various animals was observed

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TABLE 1
A List of Deities and their Vahanas/Companions in the Hindu Faith

<i>Deities</i>	<i>Vehicle/Companions</i>
Brahma (God of Creation)	White Swan
Durga (Goddess who killed the Demon)	Lion/Deer
Mahaganapathi (Elephant God)	Shrew
Indra	Iravatham (White elephant)
Sastha	Tiger
Siva (God of annihilation)	Bull (Nandi)/Serpent
Srikrishna	Cow/Panchajanya (Shell)
Subramanya (Army chief of Gods)	Peacock
Vishnu (God of existence)	Kite(Garuda)/Serpent
Yama (Lord of death)	Buffalo

and described in the ancient Indian Classics (i.e., Mahabharatha, Ramayana, Upanishats, etc.). Many species of animals were described as “Vahanas” or the “vehicles” of various deities in Hinduism. This also reveals indirect evidence of knowledge about the behaviour and the utility of these animals during those ancient periods. Sculptures and drawings of a number of deities also show these “Vahanas” with their characteristic behaviour patterns (Table 1). This has been responsible for creating love and affection for animals in ancient times in India. For example, the depiction of the shrew as the Vahana of Maha Ganapathi, is interesting, as Ganapathi is several times heavier than the small shrew. This may be because the voracious nature of this insectivore and its effectiveness in controlling insect and rodent pests was precisely known during that ancient civilization. Such animals are still considered as “sacred animals” by their devotees.

TABLE 2
The Number of Papers Presented at ESI Annual Conferences

<i>Year</i>	<i>Place of the Conference</i>	<i>Number</i>
1980	Madurai Kamaraj University, Madurai	69
1981	University of Agricultural Sciences, Bangalore	83
1982	University of Calicut, Calicut	61
1983	St. John's Medical College, Bangalore	61
1984	University of Kerala, Trivandrum	87
1985	The New College, Madras	118
1986*	Annamalai University, Annamalai	51
1987*	University of Agricultural Sciences, Bangalore	44

*Announcements of the conferences were delayed.

Even now in India, Brahmins who worship Ganapathi never kill shrews even though this animal invades kitchens and is a nuisance in the home.

SYSTEMATIC STUDIES IN ANIMAL BEHAVIOUR IN INDIA

Systematic observations on animal behaviour is a recently evolved branch of biological research in India, initiated only in late 1950's and carried out by a few scientists independently. Dr. M.D. Parthasarathy of the Bangalore University is one of the pioneers among the ethologists of India. His major field of investigation was the social and reproductive behaviour of bonnet macaques in Bangalore (Rahman & Parthasarathy, 1969a, b).

ETHOLOGICAL SOCIETY OF INDIA

The Ethological Society of India (ESI) was formed in 1970 by a small group of zoologists, motivated to do so by S.A. Barnett who was

TABLE 3
Scientific Sessions Organised During the Annual Conferences of the Ethological Society of India

<i>Title of Sessions</i>
Animal economics
Animal orientation and communication
Avian ethology
Behavioural adaptations
Behavioural development
Behaviour during solar eclipse (1980)
Behavioural physiology
Brain and behaviour
Cognitive ethology
Biological rhythms
Environment and behaviour
Ethology and conservation of endangered species
Ethology of pests
Evolution and behaviour
Feeding behaviour
Habitat ethology
Hormones, pheromones and behaviour
Invertebrate behaviour
Reproductive behaviour
Sociobiology
Vertebrate behaviour

then at the Australian National University. Barnett organised a workshop on animal behaviour at the University of Agricultural Sciences, Bangalore, in 1970. At the end of this workshop the participants laid the foundation for the ESI. This Society was registered under the Indian Society Act as a voluntary body with clearly defined aims and objectives.

The ESI has been organising annual conferences every year since 1972. Today, the annual conference of the ESI is the best forum for discussions on animal behaviour in India (Table 2). Diverse sessions were held during these symposia (Table 3). A second workshop on animal behaviour was organized under the auspices of the ESI at the Central College, Bangalore University, Bangalore in 1977 by Bruce Johnson then at the University of Tasmania, Australia.

TABLE 4
Centres of Research in Animal Behaviour in India

<i>Place</i>	<i>Institution</i>
Aligarh	Aligarh Muslim University
Annamalai	University of Annamalai
Bangalore	Bangalore University*
	University of Agricultural Sciences*
	Indian Institute of Science*
	St. John's Medical College
Bhavanagar	Bhavanagar University
Bombay	Bombay Natural History Society
Calicut	University of Calicut*
Dehra Dun	Indian Institute of Wildlife
Gorakhpur	University of Gorakhpur
Jaipur	University of Rajasthan
Jodhpur	University of Jodhpur*
	Central Arid Zone Research Institute*
Madras	Layola College*
	Entomology Research Institute*
Madurai	Madurai Kamaraj University*
Mysore	University of Mysore**
Simla	University of Himachal Pradesh**
Trichur	Kerala Forest Research Institute
Trivandrum	University of Kerala*
Varanasi	Banaras Hindu University*

*Institutions where animal behaviour is of prime importance in India.

**Psychologists; others are zoologists.

CURRENT STATUS OF ETHOLOGY IN INDIA

The status of research and teaching in ethology in India was assessed by Barnett (1971), Johnson, Krishnamoorthy, & Phaniel (1984), Alexander (1985), Sridhara (1986) and Sridhara, Krishnamoorthy, Kale, & Shrihari (1987). These analyses revealed that there has been a gradual increase in the availability of books and scientific journals in the field of animal behaviour in India. The number of workers has increased and the fields of investigation in the area of ethology have diversified. Sridhara (1986) reported that the thrust was in areas concerned with social behaviour, feeding, reproduction, communication, rhythms, and responses to environment. Table 4 gives the major centres in India where ethology is getting considerable attention. Table 5 gives the animal species so far studied in ethological research in India.

TABLE 5

A List of Animals Observed in Behavioural Studies in India

-
- A. *Mammals*
Bandicoot rat, *Bandicota bengalensis*
Black buck, *Antilope cervicapra*
Blue bull, *Boselaphus tragocalemus*
Bonnet monkey, *Macaca radiata*
Cattle, *Bos indicus*
Chital, *Axis axis*
Common Indian mongoose, *Herpestes edwardsi*
Domestic dog, *Canis familiaris*
Elephant, *Elephas maximus*
Fruit bat, *Pteropus giganteus*
Field mouse, *Mus booduga booduga*
Goat, *Capra sp.*
Giant squirrel, *Ratufa indica*
Guinea pig, *Caira porcellus*
Hanuman langur, *Presbytis entellus*
Hog deer, *Axis porcinus*
Insectivorous bat, *Taphozous melanopogon*
 Hippocorleros bicolor
 Rhinopoma hardwickei
Indian gerbil, *Tatera indica*
Indian palm squirrel, *Funambulus palmarum*
Lion-tailed macaque, *Macaca silenus*
Musk shrew, *Suncus murinus*
Nilgiri tahr, *Hemitragus hylocrius*

TABLE 5 (*Continued*)

-
- Nilgiri langur, *Presbytis johni*
 Rhesus monkey, *Macaca mullata*
 Rabbit, *Oryctolagus cuniculus*
 Rat, *Rattus norvegicus*
 Slender loris, *Loris tardigradus*
 Sambar deer, *Cervus unicolor*
 Spiny field mouse, *Mus platythrix*
 Wild dog, *Cuon alpinus*
 Wild house mouse, *Mus musculus castaneus*
 White mouse, *Mus musculus*
- B. *Birds*
- Barbets, *Megalaima viridis*, *M. rubricapilla*
 Blue rock pigeon, *Columba livia*
 Budgerigoes, *Melopsittacus undulatus*
 Common babbler, *Turdoides caudatus*
 Crow pheasant, *Centropus sinensis*
 Hoopoe, *Upupa epops*
 Indian little grebe, *Podiceps rufficollis*
 Jungle babbler, *Turdoides striatus*
 Koel, *Eudynamis scolopaea*
 Malabar pied hornbill, *Anthraceroceros coronatus*
 Openbilled stork, *Anastomus oscitans*
 Purple sunbird, *Nectarinia asiatica*
 Parakeet, *Psittacula krameri*
 Red wattled lapwing, *Vaniellus indicus*
 Starling, *Sternus vulgaris*
 Shama, *Copsychus malabaricus*
 Spotted munia, *Lonchura punctulata*
 Weaver bird, *Ploceus philippines*
 Whistling thrush, *Myiophoneus caenileus*
 Yellow wattled lapwing, *Vaniellus malabaricus*
- C. *Reptiles*
- Checkered keelback water snake, *Xenochrophis piscator*
 Garden lizard, *Calotes versicolor*
 Indian cobra, *Naja naja*
 Indian water snake, *Natrix piscator*
 Spiny tailed lizard, *Uromastix hardwickii*
- D. *Amphibians*
- Apodan, *Ichthyophis beddomi*
 Indian bull frog, *Rana sp.*
 Toad, *Bufo melanostictus*

E. *Fishes*

Air breathing Teleosts, *Clarias batrachus*
Clandra punctatus

Carp, Rohu, *Labeo rohita*
 Mrigal, *Cirrhinus mrigala*

Cat fish, *Mystus montanus*

Cyprinoids, *Puntius stigma*
Gambusia affinis
Labistes reticulatus

Eel, *Pisodonophis boro*

Flat head, *Platycephalus indicus*

F. *Mollusca*

Cockle, *Anadara rhombea*

Oyster, *Crassostrea madrasensis*

Snail, *Planispira vittata*

Slug, *Mariaella dussumier*

G. *Arachnida*

Pseudoscorpions, *Anagarypus asiaticus*
Compsaditha indica
Hygroshelifer indicus
Lechytia indica
Oratemnus indicus
Stonatemnus indicus
Tyrannochthonius indica

Scorpion, *Heterometrus fulvipes*
Merobuthus tamulus tamulus

Spiders, *Latrodectus hasseltii*
Heteropoda venatoria
Cyrtophora citricola
C. cicairosa

Mites

Oribatid mites, *Pelokylla malabarica*

Ticks

Hylomma dromedarii

H. marginatum

H. revipunctata

H. hussaini

H. *Crustaceae*

Freshwater prawn, *Penaeus latisuleatus*
Macrobrachium lamerrii

Field crab, *Paratelphusa hydrodromous*

TABLE 5 (Continued)

Fiddler crab, <i>Ucalactea annulepis</i>
Hermit crab, <i>Clibanarius longitarsus</i>
Marine crab, <i>Dorippa polita</i>
I. <i>Insecta</i>
Army worm, <i>Mythimna separata</i>
Aphids, <i>Myzus persicae</i>
<i>Rhopalosiphum padi</i>
<i>Hydophis coriandri</i>
Bag worm, <i>Uania crameri</i>
Braconids, <i>Metioridea hutsoni</i>
Black carpenter ant, <i>Camponotus compressus</i>
Black headed caterpillar of coconut, <i>Opisina arenosella</i>
Cockroach, <i>Periplaneta americana</i>
Chalcid wasp, <i>Brachimeria lasus</i>
<i>B. nephantidis</i>
<i>B. nasolai</i>
<i>B. intermedia</i>
<i>B. podagrifa</i>
Dragon fly, <i>Potamarcha congener</i>
Eulophids, <i>Melitobia</i> sp.
Fig wasp, <i>Kradibia gestroi</i>
Fish louse, <i>Argulus foliaceus</i>
Fruit fly, <i>Dacus dorsalis</i>
Fire ant, <i>Soleropsis germinata</i>
Grasshoppers, <i>Heeroglyphus nigrorepletus</i>
<i>Poecilocerus pictus</i>
Giant water bug, <i>Lethocerus indicus</i>
Honey bees, <i>Apis dorsata</i>
<i>A. florea</i>
<i>A. indica</i>
Ichneumonids, <i>Campoletis chlorideae</i>
Leaf webber, <i>Nephopteryx eugraphella</i>
Mosquitoes, <i>Culex pipens</i>
<i>Armigeres subalabatus</i>
<i>Aedes albopictus</i>
<i>Anopheles stephensi</i>
Membracids, <i>Leptocentrus leucarpis</i>
<i>Otinotus oneratus</i>
<i>Oxyrachis terandus</i>
Paper wasp, <i>Ropalidia marginata</i>
Plant bugs, <i>Chrysoions purphreus</i>
<i>Dysdercus angulatus</i>

Plant hopper, *Nephotettix virescens*
N. nigropictus
Nilaparvata lugons
Sogatella jurcifera
Raduvid bug, *Coranus vitellinus*
Rice moth, *Corcyra cephalonica*
Silk worm, *Bombyx mori*
Philosamia ricini
Social wasp, *Ropalida cyathiformis*
Spotted leaf beetle, *Henospi lachna septima*
H. implicata
Syrphid fly, *Aphidophagous syrphidae*
Termite, *Odontotermes wallonensis*
Postelectrotermes nayari
Water scorpion, *Laccotrephes griseus*

J. Annelida

Eudrilus eugeniae
Earth worm, *Dichogaster bolavi*
Dravida willisi
Lampito mauritii
Lenngaster pusillus
Octochactiona surensis
Pheretima sp.
Ocnerodrilus occidentalis
Freshwater leech, *Hirudo birmanica*
Nereids, *Ceratonereis costae*
C. burmensis
Nereis chilkaensis
Lycastis indica

K. Platyhelminthes

Tape worm, *Raillietina tetragona*

Although India is far behind achieving the objective of making animal behaviour a major branch of biological research, the progress in this branch during the past 15 years is quite satisfactory. However, most of the investigations are superficial and detailed investigations are warranted. Further, more emphasis should be given to field oriented investigations rather than to laboratory experiments. This would encourage utilization of its applications in areas of pest control, management of domestic, farm and laboratory animals and in the conservation and management of wild animals.

The Department of Science & Technology under the Ministry of Science & Technology of the Government of India has established a subcommittee on Ecology and Ethology. On the basis of these devel-

opments, the present growth of research in animal behaviour in India will steadily continue. More groups of researchers will emphasise field oriented applied ethology in the coming decades, and ethology will emerge as a major field of research and teaching in biology in India.

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FIELD METHODS NOTE

IDENTIFICATION OF INDIVIDUAL *APLYSIA* *SPP.* BY HEAD PIGMENT PATTERNS

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To study social, reproductive and migratory behavior, in *Aplysia* spp. individual identification is important (Switzer-Dunlap, Meyers-Schulte & Gardner, 1984; Zaferes, Skolnick & Tobach, 1988). Identification has been implemented by tagging techniques using floy tags (Audesirk, 1975), DYMO plastic tape (Nishiwaki, Veda & Makioka, 1975), safety pins with colored tape codes (Lederhendler & Tobach, 1977; Zaferes, et al., 1988), and nylon line (Migenis-Lopez, personal communication, 1987). Tags have been attached to most parts of the *Aplysia* body, and have been reported not to remain attached to the animal for prolonged periods, especially in the field. Nishiwaki et al. (1975) tagged and surveyed 1,427 *A. kurodai* in Nabeta Bay, Japan, over a period of 5 months. By the fifth month only one tagged animal was recaptured, and 121 loose tags were found in the waters where the *Aplysia* had been tagged. Other studies using tags in field and laboratory conditions reported similar results of lost tags (Lederhendler, Bell & Tobach, 1975; Migenis-Lopez, personal communication, 1987).

Aplysia are covered with spots and lines of pigment of different colors: purple, green, aqua, black, brown or very light tan. These colors reflect species differences and the algae eaten (Winkler, 1959). In the course of a study of *A. brasiliiana* in waters off Guayama, Puerto Rico (P.R.), it was found that no two individuals had the same pattern of pigment spots and lines on the head in the area between the buccal tentacles and the rhinophores. To verify this observation, *A. brasiliiana* were studied in the field and laboratory and *A. dactylomela* were observed in the laboratory.

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THE HEAD PATTERN IDENTIFICATION TECHNIQUE

1. Handling Technique

Animals were obtained while walking, snorkeling, and scuba diving, and were removed by hand from the substrate by sliding one's fingers under an animal's foot and gently scooping it off the substrate. Animals were picked up without touching the visceral mass or head area, to prevent the animals from contracting into a balled posture, which hides much of the dorsal surface of the head from the observer's view. When held with minimal pressure with its head slightly lower than its tail, the *Aplysia* generally stretched its neck and head, providing a full view of the head pattern (Figure 1). An *Aplysia* will usually remain inactive in this position for at least 20 sec.

2. Characteristics

Each time an animal was found in the field, the pattern was drawn onto a waterproof writing slate, and notes were made of when and where the animal was found, its volume and the characteristics of the animal's markings. The characteristics recorded in addition to head pattern were as follows:

1. rhinophores: a. symmetrical or asymmetrical
 b. striped or not striped



FIGURE 1. Procedure used to hold an *Aplysia* while recording its head pattern.



B

FIGURE 2. A. Photograph of the head area of an *Aplysia* taken in the field May 14, 1987. The two rhinophores on top and the buccal tentacles on the bottom of the picture are partially contracted. B. The head pattern drawing recorded when photograph "A" was made. The two dark lines on top represent the rhinophores. Other characteristics recorded on the slate: 1. rhinophores symmetrical and unmarked 2. unmarked foot 3. none (scars, identifiable patterns) 4. a. broken b. large c. thin 5. 72 ml.

2. foot: spotted or unmarked
3. body/head: scars, distinguishable markings such as geometric patterns or lumps on the body
4. pigmented circles on body wall:
 - a. continuous or broken;
 - b. large, intermediate or small;
 - c. thick or thin
5. Each animal's volume was measured by placing it in a 1000 ml graduated cylinder filled partially with sea water. Otsuka, Rouger, & Tobach (1972) found that the amount of sea water an *Aplysia* displaced was equal to its dry weight.

The entire process of recording a head pattern, volume and physical description took approximately 1-3 min depending on the animal and water conditions (Figure 2). At the end of each survey, the information from the slate was copied onto index cards. Photographs were

taken of the head area with a Nikonos V camera from time to time when the *Aplysia* was recaptured to check for drawing accuracy and to record changes that may have taken place.

LOCATION IN WHICH ANIMALS WERE FOUND AND DESCRIBED

1. Field sites (Table 1)

a) Guayama, Playa de Jobos (Southern P.R.)

Daily surveys were made hourly during daylight in an area approximately 15 m wide and 30 m long. Animals were individually identified by using both head pattern and tagging with a safety pin with colored tape technique (Lederhendler & Tobach, 1977). Several animals lost their tags on one or more occasions, but the head pattern technique proved helpful in the identification of these animals. A total of 17 *A. brasiliiana* were found, of which 14 animals were seen on more than one day (Table 1). At the end of four or five days most animals' head patterns could be recognized easily on sight.

b) Fajardo, Seven Seas Beach (Northeastern P.R.)

This site was studied from May 12 to June 8, 1987 during daylight hours, and during two night observations from sunset to sunrise. Individuals were identified by the head pattern technique. A total of 70 animals were found, of which 42 animals were seen on more than one day (Table 1). There were no observable changes in the head pigment patterns of these animals found more than once. Animal volume was used to group the animals into three categories, small (20 ml - 45 ml), medium (50 ml - 75 ml), and large (80 ml - 105 ml), to make the process of locating specific head patterns easier.

c) Palmas del Mar (Southeastern P.R.)

A total of 51 animals were found and identified with the head pattern technique, of which 17 were seen on more than one day (Table 1).

2. Laboratory

As the animals were observed in groups, individual identification was necessary. The head pattern technique was used as the identification method.

a) Nine *A. dactylomela* and 20 *A. brasiliiana* were brought to the Comparative Psychology Research Group Laboratory in the American Museum of Natural History for group observation in several social behavior experiments from July 7 through August 25, 1987 (Zafres & Tobach, in preparation). Animals were maintained in individual

TABLE 1
Number of *A. brasiliiana* Identified by Head Pattern

Number of Animals	Total Number of Days Seen	Median Number of Days between First and Last Sightings	Number of Days between First and Last Sightings	
			Least	Most
A. Playa de Jobos, March 14, to 23, 1987				
3	1	—	—	—
4	2*	—	—	—
1	3*	—	—	—
2	4*	—	—	—
4	5	6	5	6
3	6*	—	—	—
B. Seven Seas Beach, May 12 to June 8, 1987				
28	1	—	—	—
14	2	9	2	26
7	3	20	10	23
7	4	13	10	26
6	5	20	5	28
4	6	22.5	11	28
1	7	—	22	—
2	9#	—	27	—
1	10	—	27	—
C. Palmas del Mar, March 23 to April 1, 1987				
34	1	—	—	—
13	2*	—	—	—
4	3*	—	—	—

* Found on consecutive days.
Both animals seen during an interval of 27 days.

mesh cages when their social behavior was not being observed and recorded.

b) Identification reliability check.

During the first week, before the observations began, two observers studied photographs and both drew head patterns of each animal. Each observer was then presented with a drawing of each animal without any code name identification, and was able to then pick out the individual animal in a group situation with 100% accuracy without consultation between the observers. There were not differ-

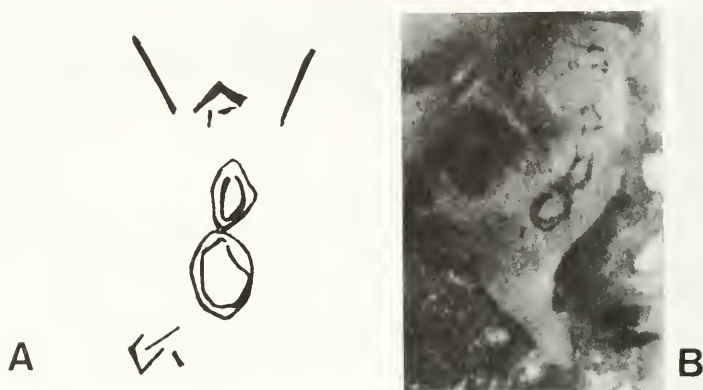


FIGURE 3. Drawing and photograph of an *A. brasiliana*. A. The head pattern of an *Aplysia* recorded on a slate during a field observation on June 2, 1987. B. The head of that same *Aplysia* photographed in the laboratory on August 16, 1987.

ences when their own or the other observers' drawings were used. Head patterns were recorded for all animals every 10 to 14 days by drawings and/or photographs. Figure 3 shows the pattern of an animal drawn in the field and photographed in the laboratory. No changes in the head pattern of any animal were ever observed.

DISCUSSION

The method has proved useful in field and laboratory with populations of limited size (under 70), or where photographs can be made easily. Head pattern identification may not be necessarily the method of choice in such extensive studies as that by Nishiwaki et al. (1975) where several hundred animals were surveyed, but it can be an ancillary tool.

It is also possible that head patterns may be useful for species as well as for individual identification. The population of *A. dactylomela* in the laboratory were easily distinguished from the *A. brasiliana* by their head patterns with the head pattern of *A. dactylomela* having many fine cracks and lines, as well as more complicated spot and circle patterns than the head patterns found on *A. brasiliana*.

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BOOK REVIEW

Levinthal, Charles F. (1988). *Messengers of paradise: Opiates and the brain.* New York: Anchor Press/Doubleday.

This book begins with a thoughtful history of opium. For the history buff in all of us this chapter provides numerous fascinating insights. We learn that the intense desire for Chinese tea by the English was a factor in promoting the use of opium in China. Godfrey's Cordial, a mixture of opium with sassafras and molasses, was immensely popular in Coventry, England as a medication to quiet noisy children. In fact, it was so popular that at one point in time 12,000 doses were sold weekly in this small English town. Similar events are traced in the United States where such mixtures were marketed in the late 1800's under the name Laudanum by such bulwarks of American society as the Sears, Roebuck catalog. The cost was about six cents an ounce. The development of heroin and other opium derivatives is then traced. The ultimate conclusion that the author has been leading us toward is achieved—some form of opiate receptor exists in the brain and spinal cord and that the body may be producing its own natural opiates.

Having set the stage, we digress (Chapters 2 and 3) from the main theme for a basic review of the evolution, structure, and mechanical processes of the human brain. While this material is presented on a non-technical level it is nevertheless quite informative. Several of the photographs alone make the book a valuable addition. My favorites were the pictures of the Lavery Electric Phrenometer, a 1907 automated machine for phrenological examination; and the brain of Leborgne (also known as "Tan Tan") that propelled Paul Broca to fame and prominence.

Returning to the main thrust of the book, we consider the period 1971-1973 (Chapter 4). It was during this time that the search for the opiate receptor was being conducted in earnest. From the groundbreaking research proposal of Avram Goldstein in 1971 until the simultaneous discovery of the receptor in 1973 by Pert and Snyder at Johns Hopkins, Simon at New York University, and Terenius at Uppsala in Sweden, the author gives us a fascinating view of this research process. Clearly, scientists are people—very competitive people.

Having established the existence of opiate receptors, the search for the opiate-like substance(s) themselves intensified. During the

period 1973-1979 (Chapter 5), 69-year-old Hans Kosterlitz and his younger colleague John Hughes loom as pivotal figures. It was in their laboratory in Aberdeen, Scotland that the initial identification of the amino acids comprising the "morphine-like peptide" under study, was made. By December, 1985, the exact amino acid sequence was made known and the name "enkephalin" given by these investigators to this compound. As the author clearly points out, this finding ushered in a whole new research era. Half a decade later more than a thousand articles related to endogenous opiates would appear. Having now completed one-half of this book, it was refreshing to note that Levinthal's approach showed no signs of wavering. The book continued to be personable and interesting, yet thoroughly laced with appropriate and accurate scientific examples.

In part 2 Levinthal examines the significance and importance of the endorphins for behavior.

Couched in terms of being steps toward paradise, we are told that the "First Step Toward Paradise" (Chapter 6) involves the analgesic properties of the endorphins and the relationship of such effects to basic survival. The inclusion of a discussion of opiate and non-opiate pain systems and the tentative linking of opiate analgesia with pain avoidance is commendable.

The "Second Step Toward Paradise" (Chapter 7) concerns the role of the endorphins in promoting social contact. Here we are introduced to the intriguing theory that social contact and behavior typically result in the natural release of endorphins, a powerful reinforcer. For those individuals who are unable to experience reinforcement in this natural manner, externally administered opiates (i.e., drug addition) are clearly an alternate source of such effects. Additionally, Levinthal makes a compelling case for the involvement of the endorphins in autistic behavior and depression. If you have not encountered this material previously, it is both fascinating and thought provoking.

In Chapter 8 we take the "Third Step Toward Paradise." Based upon the research of Lewis and Mishkin that demonstrated a distinct system of Mu-type opiate receptors extending from the amygdala to the inferotemporal cortex and ending in the occipital lobe, it is proposed that endorphins may influence the emotional aspects of our visual perceptions and even our language. The author speculates upon the possible involvement of this system in the "high" or "thrill" that a favorite musical experience can bring, prosody, autism, and even obsessive-compulsive disorders. While all of the requisite data are not yet in, it is clear that these are not idle speculation.

The final chapter attempts to bring us "A Glimpse Of Paradise." Whether it be the "flow experience" proposed by psychologist Mihaly Csikszentmihalyi, the "effective surprise" of Jerome Bruner, or any of one's most intense and creative experiences, Levinthal suggests their

distinct relationship to the endorphins. This linkage, as are the others described previously, is quite logical and not without substantiation.

In summary, this is a well-written, interesting, and provocative work. Regardless of your own research specialty, you will find the knowledge gained to be well worth the time you invest in reading. Should you desire to go further, the references for each chapter have been carefully and thoroughly documented.

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